CASA DA MÚSICA - PORTO

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ABSTRACT

In Porto a new concert hall is under construction. The new hall will be shoebox shaped with specific solutions to ensure sufficient strong lateral reflections. Acoustically, the main challenge is the front and back walls being entirely made of glass, to give the feeling that the rooms are open to the city. As well as keeping out noise from exterior sources these transparent walls have to be designed such that they contribute to the sound distribution within the hall. The glass walls of the Casa da Música's concert halls will have horizontally waved structures. To be sure that the transparency of the hall is complete also the canopy will be transparent.

INTRODUCTION

In the words of the architect, the Casa da Música will have 'an expressive, rock-like shape'. It has been projected near the Rotunda da Boavista, a square just outside Porto's historic city centre. In addition to two concert halls, various rehearsal areas, a recording studio and a restaurant, the design provides for a music shop, a café, a roof terrace and facilities for education and 'cyber-music'.

The program for the Casa da Música focuses on a main auditorium with a capacity of approximately 1400 seating. The auditorium is mainly meant for symphonic music, but also musical theatre should be possible. The consequence of this choice implies variable acoustics and a lot of technical solutions like a moving catwalk or technical bridge and light bridges above the ceiling.

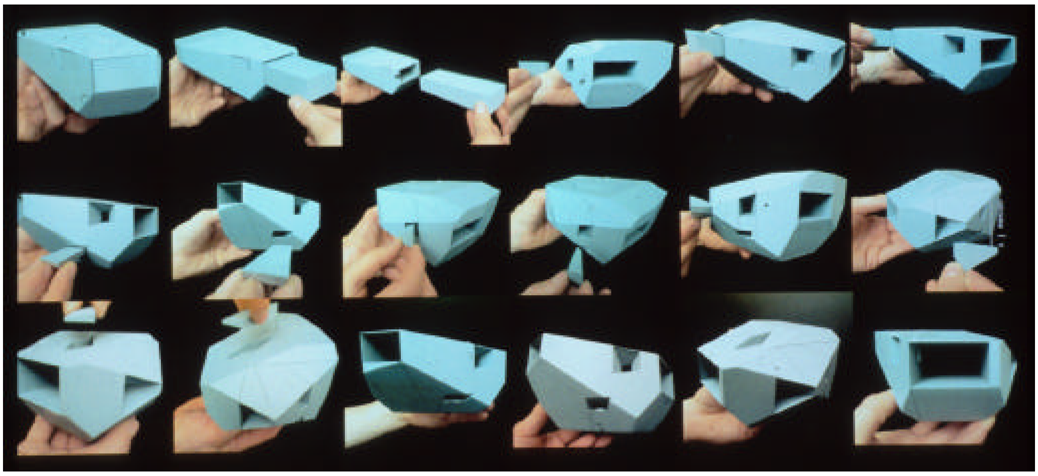


Figure 1: In the architectural concept the building is like a big rock holding together all different functions.

Figure 2: Interior of the hall as thought by the architect

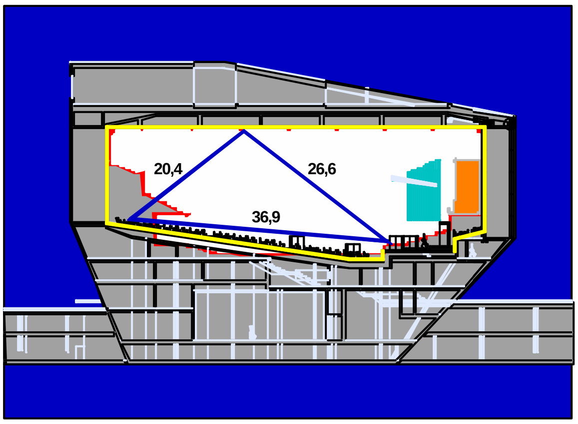
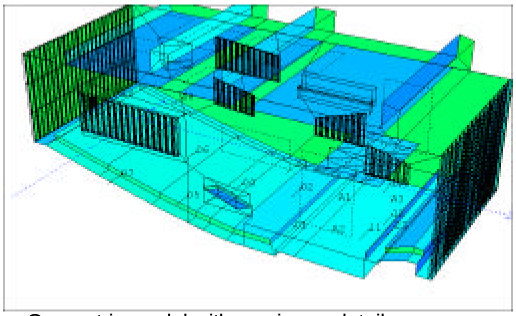


Figure 3: Section over the main auditorium.

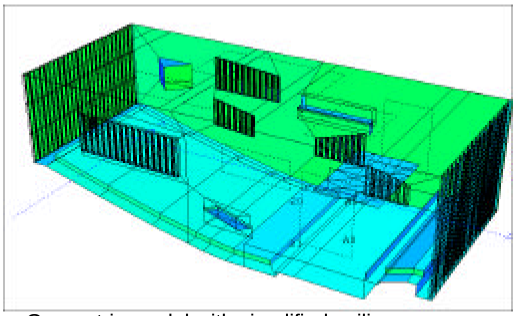
In figure 1 the architectural concept is elucidated: the building is like a big rock (or diamond) in which the specific functions are brought in like drawers. The giant rock will have a height of approximately 40 m, rise up out of parking to dominate the whole environment. The building will be constructed in white concrete. The real diamond in the building will be the main auditorium. Figure 2 illustrates the concept for the main auditorium in the competition phase. The hall is thought like a big shoebox with transparent rear and back wall. The audience is seated in one raked surface so they can look out to the Rotunda da Boavista. Musicians can see part of Porto behind the audience. The shape of the auditorium is a logic continuation of the design concept. The width of the hall will be 22 m, the hall is approximately 53 m deep and will have a height of 17,5 m. The volume of the hall is calculated to be 17.500 m^3. Its shape and dimensions show big similarity with the Grosser Musikvereinsaal in Vienna as can be seen in figure 3.

ROOM ACOUSTICAL COMPUTER SIMULATIONS

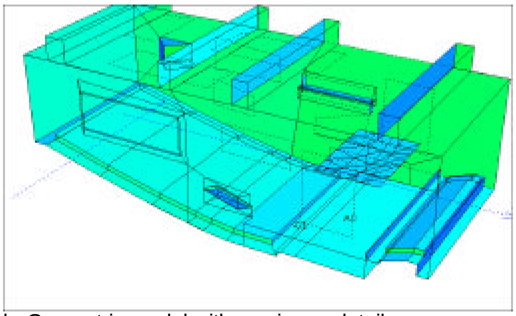
For the room acoustical simulations CATT-acoustics has been used. One of the questions to be answered was the magnitude of detail necessary to get reliable answers. Because the hall is also meant for musical theatre performances all kind of technical arrangements will be introduced. As a consequence we had to deal with technical bridges above the ceiling. The computer program has the possibility to define the diffuse reflection of surfaces. For the corrugated glass it was of interest to study the necessity of detailing the surface or just attribute a factor to this surface. For this goal different geometric models are constructed and compared.



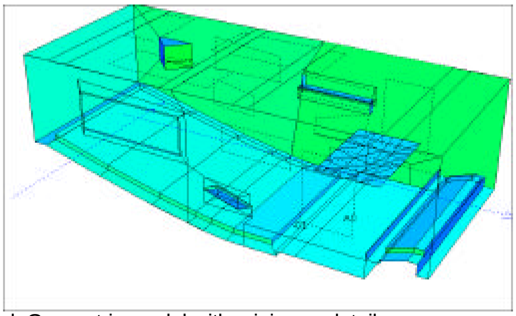
a. Geometric model with maximum detail



c. Geometric model with simplified ceiling



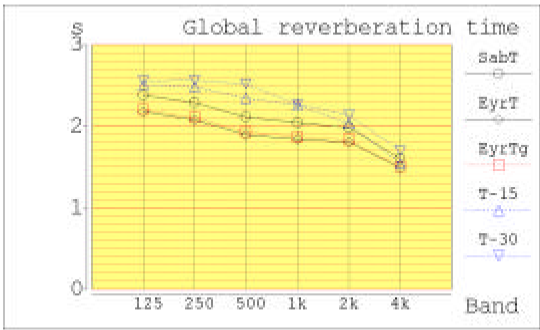
b. Geometric model with maximum detail
corrugated glass as one surface



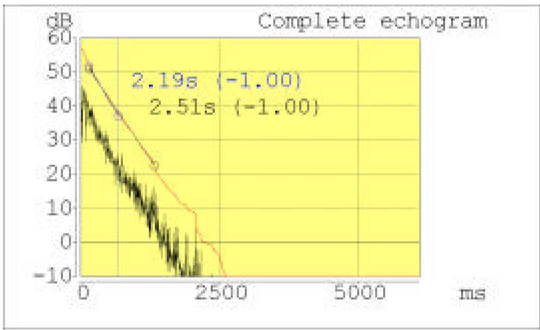
d. Geometric model with minimum detail
corrugated glass as one surface

figure 4: Geometric models for the Casa da Música

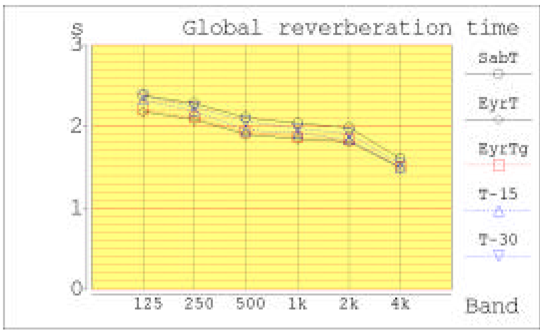
Point of discussion was the reliability of the reverberation time calculated with the model and the influence of the diffusitivity of the lateral walls. The next graphs show the differences between calculations with non-diffuse (specular reflecting) lateral walls (a and b) and fully diffuse lateral walls (c and d) on the reverberation time. These kinds of calculations proof the usefulness of suchlike models to the study the effectiveness of different measures in a concert hall.



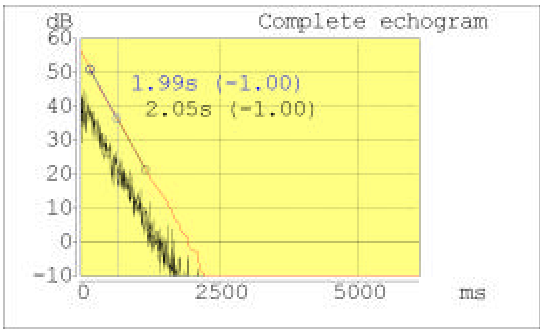
a.



b.



c.



d.

Figure 5: Estimated reverberation time and echogram in case of non-diffuse (a and b) lateral wall finishing and diffuse (c and d) lateral wall finishing.

With the fully diffuse lateral walls the difference between the calculated T_{sabine} and T_{30} almost disappears while there is a big difference in the situation with non-diffuse lateral walls. The graphs show that in case of non-diffuse lateral walls the computer program adds energy in the tail of the reverberation curve.

SCALE MODEL MEASUREMENTS

As a design and verification tool for the acoustical consulting of large concert halls, research in a scale-model is also important and often used. Such a model is mainly used to detect strong late reflections and the distribution of energy in the concert hall. In this specific project the need of scale model measurements was important because of:

- The shape of the hall
- The behaviour of corrugated glass
- The treatment of the wall surfaces
- Position and number of diffusers
- Change in design (intersection, number and shape of balconies)
- Canopy position

In Figure 6 and 7 pictures of the scale model are given.

Figure 6: Interior scale model, view to stage

Figure 7: Interior scale model, view from stage

The scale of these models varies normally between 1:20 and 1:8. For the Casa da Música a model has been built on a scale of 1:10. Not only the physical size has to be one-tenth of the original hall, but also the 'acoustical dimensions' have to have the same scale. The model has been constructed of 12 mm MDF, the audience is simulated by egg cartons on foam, also the organ surface and galleries are simulated by sound absorbing material, the canopy is made of thin transparent material and the corrugated glass surfaces are also on scale as were the QRD diffusers.

Two types of test source were used. An 'omnidirectional' loud- speaker and an acoustic impulse, generated by an electric spark.

Loudspeaker

In the measurements with a loudspeaker as the source, the test signal used is a MLS-signal (Maximum Length Sequence), with a bandwidth of 48000 Hz. With a 1 to 10 scale, this covers the most significant frequencies for acoustics evaluation.

The MLS-signal is a so-called pseudo-random noise signal. It is an optimized excitation signal for correlation based impulse response measurements. With the derived impulse response, a reliable overview of the reflection pattern in the room can be produced. The measured impulse

response makes it also possible to derive room acoustic parameters such as reverberation time, early decay time and clarity, etc.. With this correlation-based measurement, a certain amount of background noise suppression is achieved, resulting in a better dynamic range and less sensitivity for disturbing signals.
The omni-directional loudspeaker has been built on a scale of one-tenth of an original decahedron, as is used for room acoustical measurements. The omni directional sound source and its spectrum, are illustrated in figure 8a.

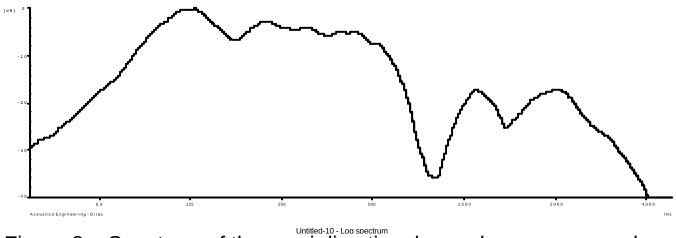
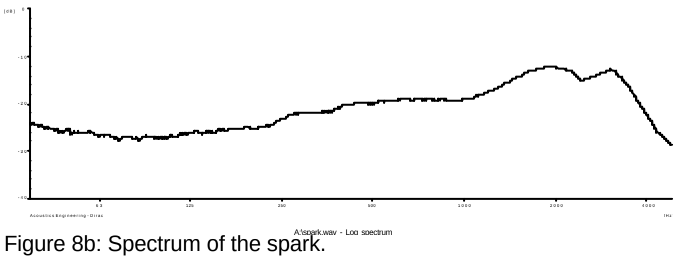


Figure 8a: Spectrum of the omni directional sound source as used.

Spark
The impulse responses have also been measured by using a spark (high voltage electric bridge). Due to its nature, this results in a very narrow impulse. The drawbacks, however, are less energy and a less perfect reproducibility. Also is this an a-synchronous measurement, thus t=0 is not defined.

In figure 8b the high voltage bridge bridge and the spectrum of the spark are illustrated.



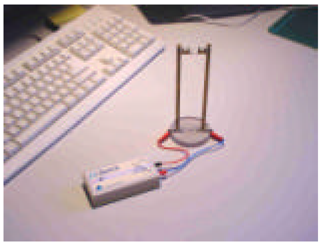


Figure 8b: Spectrum of the spark.

With the sound source a short pulse is generated and recorded with the 1/8” microphone making use of the Dirac software tool. The measured impulse responses are saved as standard Windows .WAV files that include information for unambiguous identification and interpretation.

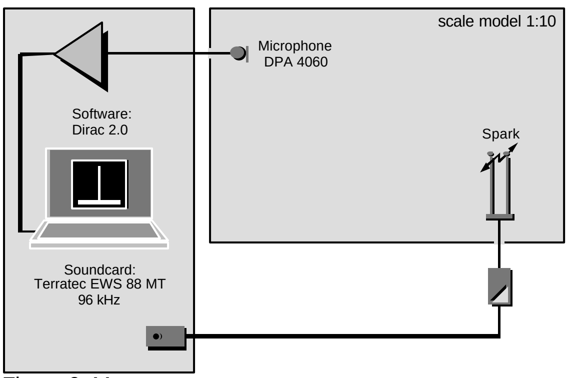


Figure 9. Measurement set-up.

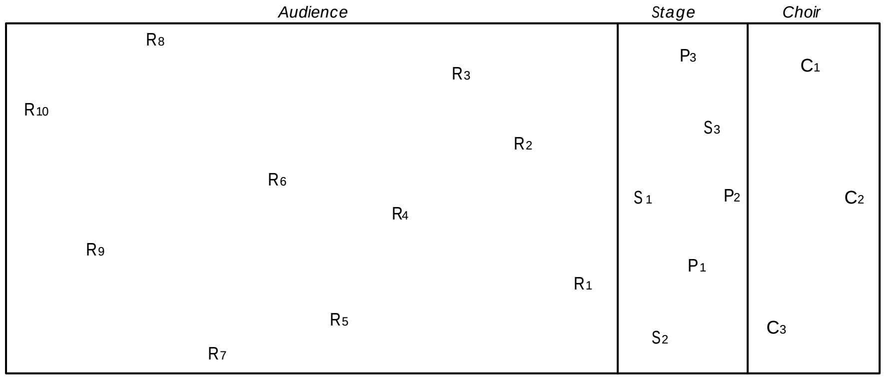


Figure 10 : Source and receiver positions.

In the scale model three source positions and 13 receiver positions have been used. The source and receiver positions were identically to the positions used in the computer simulations. For all source – receiver combinations impulse response have been recorded and analysed. Also single number quantities to describe the acoustics quality of the hall are derived (clarity, stage support). In figure 11 an example of a measured impulse response is shown.

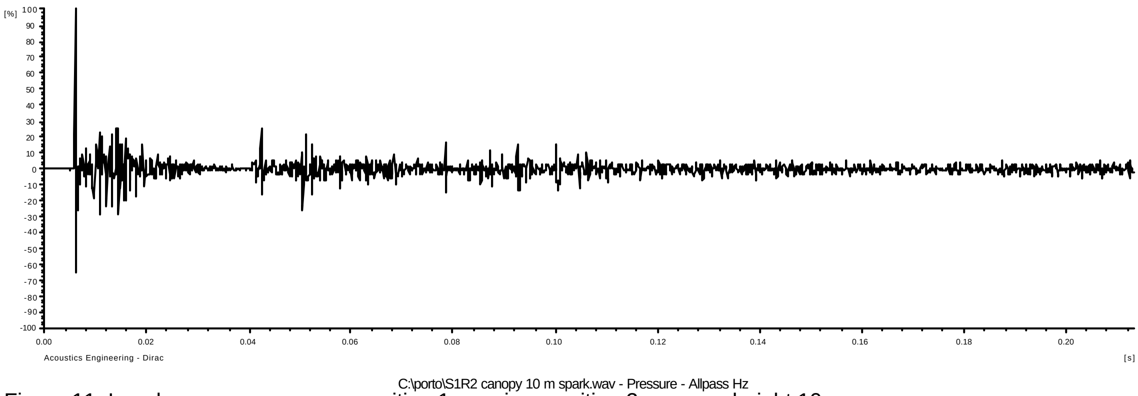


Figure 11: Impulse response source position 1, receiver position 2., canopy height 10 m

THE CANOPY

The canopy will be 12 meter long and 8 meter wide. The canopy design is convex in both horizontal directions.

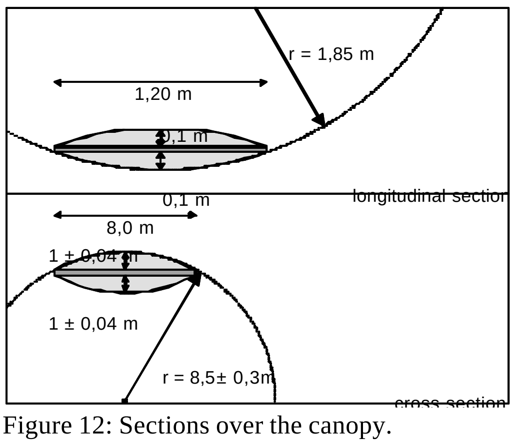


Figure 12: Sections over the canopy.

Construction of the canopy:
Upper Membrane: 200 µm, ETFE, transparent

Lower Membrane: 5 mm, Soft-PVC,
transparent, light transparency >80%
mass> 5 kg/m^2

The position and shape of the canopy has also been tested in the scale model. For different source and receiver positions impulse responses have been recorded and data have been edited. In figure 13 an example of such processing is given. The influence of the canopy and its height becomes very clear.

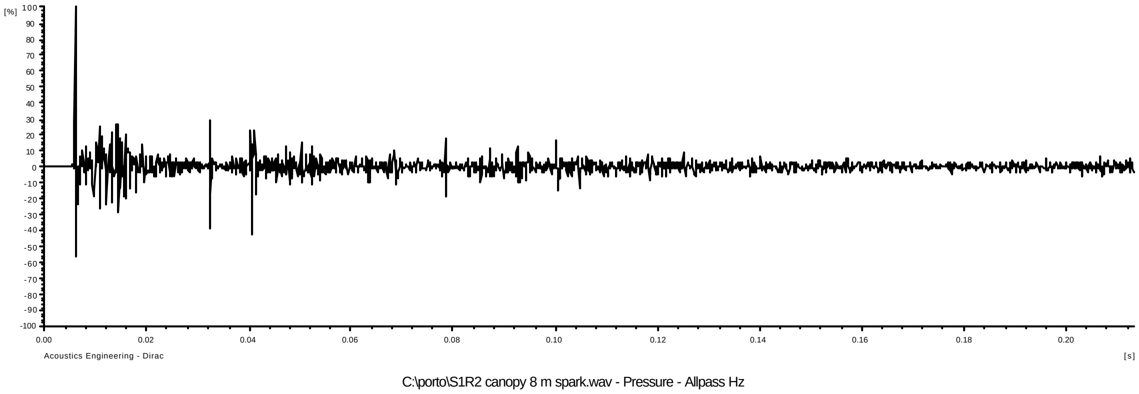


Figure 13: Impulse response source position 1, receiver position 2., canopy height 8 m

The impulse responses with source position 2 are used to calculate the energy ratio C50. In figure 14 mean the value for energy ratio C50 with two choir receiver positions and two stage receiver positions indicate the importance of the canopy. It is obvious that the height should be between 8 and 10 meter.

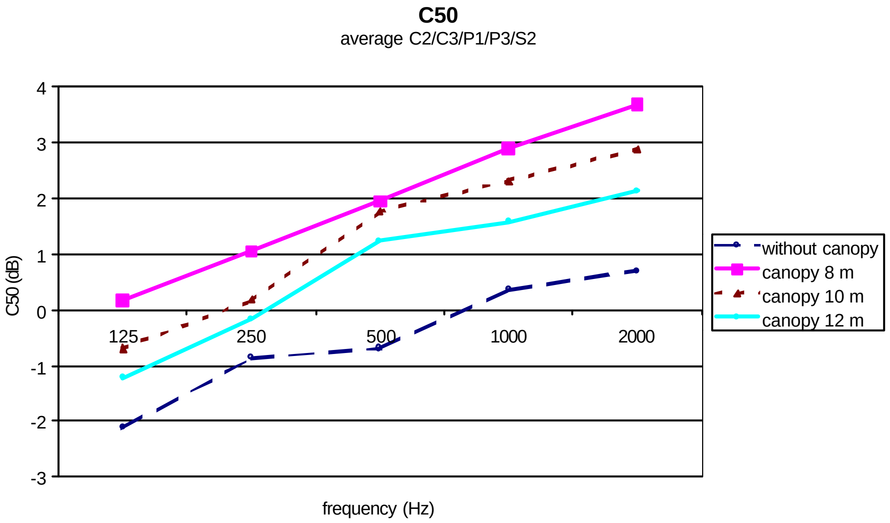


Figure 14: Calculated C_{50} for different canopy positions.

In the anechoic chamber of TNO Delft also tests have been carried out on a scale model of the canopy with dimensions of 2,0 x 2,5 m and different static pressures in the transparent cushion. The first idea was to fill the cushion with special gas to be sure to get enough reflection. It proved that bringing the cushion under pressure would give the same result. A pressure of 0,8 to 1,6 Pa is necessary to get the reflection properties we want as can be seen in figure 15.

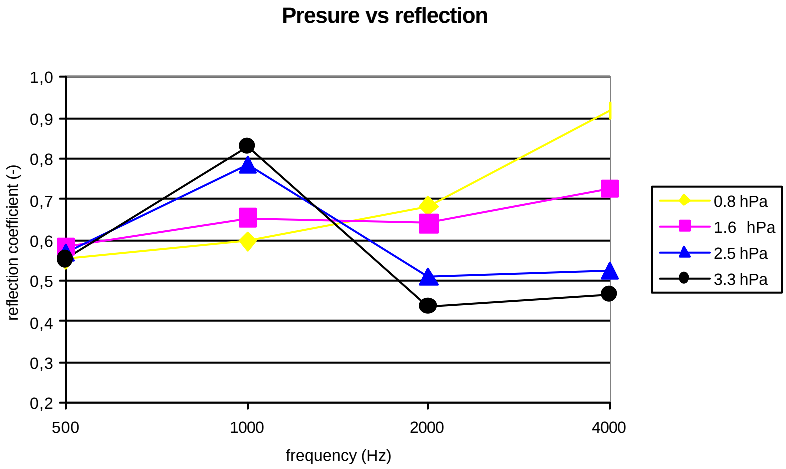


Figure 15: Reflection coefficients of canopy under different pressure conditions.

CORRUGATED GLASS

To get reliable information on the reflection behaviour of the corrugated glass measurements on a small sample on scale 1:10 have been carried out at the Institut für Technischen Akustik (ITA) from RWTH Aachen Germany where a method for measuring the random incidence scattering coefficient of surfaces or structures has been developed (lit [1]).

This method is the basis for a future ISO standard: ISO/CD 17497. The measurements are made in a reverberation room, either in full scale or in a physical scale model. The measuring results may be used to describe how much the sound reflection from a surface deviates from a specular reflection. At ITA a scale model is ready for use. (See fig 16)

On our request measurements were carried out to determine the random incidence scattering coefficient of the undulated glass, scale 1:10. As test object is used undulated steel of the same dimensions as the undulated glass. The undulated steel has been mounted in a wooden frame to close the cannelures.

Figure 16 Test sample in scale model

The results can be used for comparison purposes and for design calculations with respect to room acoustics and noise control. This is important for the project Casa da Música in Porto.

The scattering coefficient is a rough measure that describes the degree of scattered sound in contrast to the diffusion coefficient that describes the directional uniformity of the scattering. There is a need for both concepts, and they have different applications.

The degree of acoustic scattering from surfaces is very important in all aspects of room acoustics. Insufficient scattering may cause abnormal sound decay and discrepancy between calculated and measured reverberation times.

The results given in figure 17 were obtained with the corrugated glass and compared with QRD Flutter Free diffusers, also on a scale

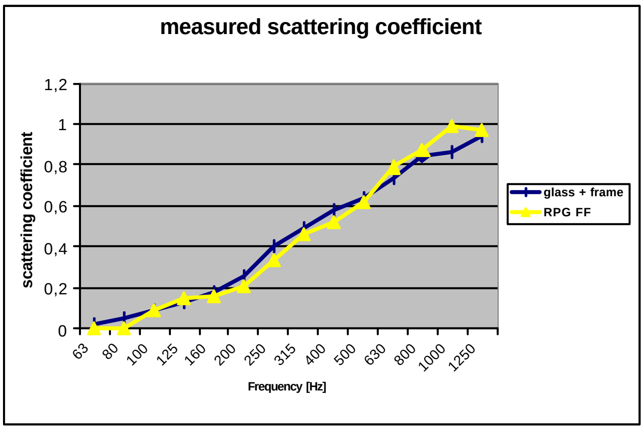


Figure 17: Measured scattering coefficient in a scale model on a scale sample of corrugated glass and RPG QRD flutterfree diffusor.

SOUND INSULATION

The new building will be situated near the Rotunda da Boavista in Porto. Traffic passes the building on three sides as can be seen in figure 18.

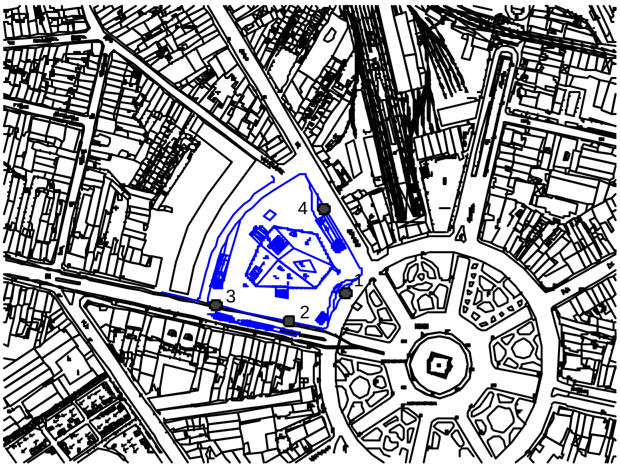


Figure 18: Building site.

The site of the concert hall thus is to be considered as noisy. The noise exposure of the building to count on is approximately 75 dB(A). Because of this high noise load the transparent walls also have to perform on sound insulation. In the acoustics laboratory Eindhoven University of Technology measurements have been carried out to determine the sound insulation of 12 and 20 mm thick laminated glass. Also a combination of these two types of glass over an ideal joint has been measured.

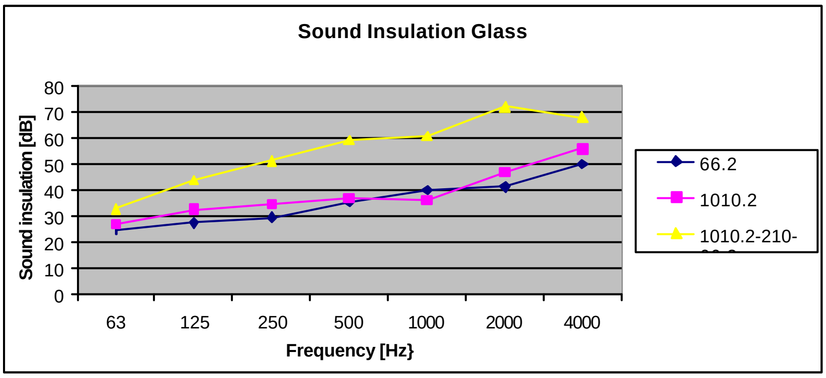


Figure 19: Sound insulation of laminated glass, measured in the acoustics laboratory of the Eindhoven University of Technology.

The data are used to predict the noise level in the foyer directly behind the first glass facade and in the concert hall. The noise reduction to be expected with the proposed solutions will be at least 70 dB(A). This will be sufficient to fulfil the acoustic criteria for the intruding noise in case the hall is used for recordings.

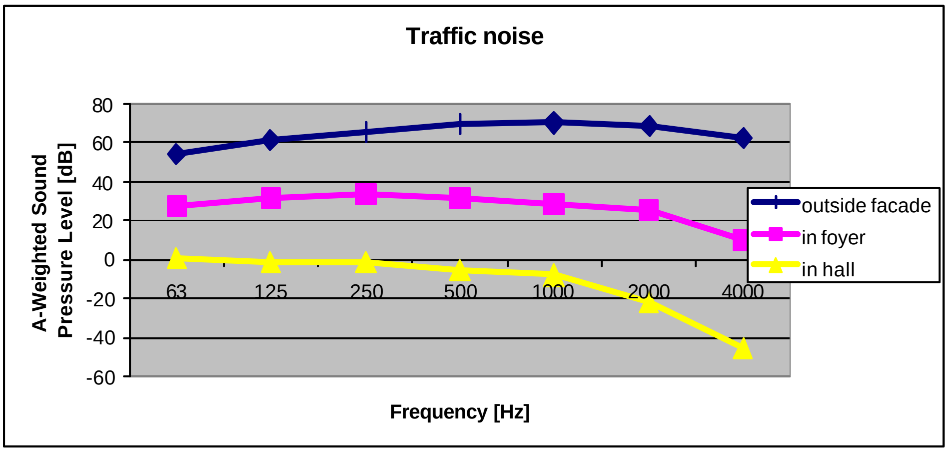


Figure 20: Estimated noise levels in the foyer and main auditorium with the application of the laminated glass.

CONCLUSIONS

Designing an enclosure for optimal acoustics asks for specific expertise on as well roomacoustics as sound insulation. Computer simulation is necessary in the comunication to the architect to show the effect of design decisions. Scale model study elucitates even more the necessity of additional measures as a consequence of difficult to understand options as for example changing wall shape with the intersection of the small auditorium, the best position of the canopy, and the shape of the transparant windows.

Casa da Música is not a standard hall. To guarantee the acoustical quality of such a hall a lot of research is needed. For this acoustical research tools are important and acoustical experiments are necessary.

REFERENCES

[1] Committee draft ISO/CD 17497, 21-07-2000.
[2] Mommertz, E., Measurement of scattering coefficients in the reverberation room – Some precision considerations, Note No.43, ISO/CD 17497 working group.